X-Band Filter

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The need for additional filtering in the 400-kW S-band transmitter was established during compatibility testing between the 400-kW transmitter and the X-band traveling-wave maser receiver. The tests showed that ranging modulation on the S-band carrier resulted in side bands on the fourth harmonic (fourth harmonic is in X-band frequency range) that were approximately −145 dBm and in the passband of the X-band receiver.

I. Introduction

The need for additional filtering in the 400-kW S-band transmitter was established during compatibility testing between the 400-kW transmitter and the X-band traveling-wave maser (TWM) receiver. The tests showed that ranging modulation on the S-band carrier resulted in side bands on the fourth harmonic (fourth harmonic is in X-band frequency range) that were approximately −145 dBm and in the passband of the X-band receiver.

In order to eliminate interference from the S-band transmitter in the X-band receiver downlink for Mariner Venus/Mercury 1973 (MVM'73), a minimum of 30-dB attenuation is required for the fourth harmonic of the S-band uplink. To provide a safety margin the specifica-

tion was written for a multimode 40-dB fourth harmonic filter. The basic specifications are given in Table 1.

Since this filter will be used in conjunction with the existing harmonic filter (described in Ref. 1), a rejection-type filter which is simpler for multimode filtering was designed. Also, the cooling requirements are minimal, as the power dissipation within the filter is a result of the passband insertion loss.

II. Summary

Varian Associates was awarded a contract to design, develop, fabricate, and test a filter capable of operation at

500-kW CW power in the 2.10- to 2.12-GHz fundamental frequency range. This filter was to provide in excess of 40-dB attenuation in the X-band (fourth harmonic) frequency range. Low-power tests show that the filter attenuation is greater than 45 dB (Figs. 1, 2, and 3). The filter is installed and operating at 400 kW with no degradation to the S-band system. Tests will be conducted to determine if the fourth harmonic interference has been eliminated in the X-band receiver.

III. Design

An important consideration in the design of the filter relates to the possible modes of propagation at the reject band frequencies. In the WR-430 waveguide, there are 29 possible modes of propagation at the fourth harmonic of the 2.10- to 2.12-GHz fundamental frequency range.

From a practical standpoint it would be extremely difficult to design a filter that would reject equally well 29 possible modes of propagation. However, at the 500-kW power level, it is not necessary to utilize a full-sized waveguide. Thus, it is possible to reduce waveguide dimensions in such a way as to greatly reduce the number of possible modes of propagation. For example, if the waveguide height (b dimensions) is reduced sufficiently, all TE_{mn} and TM_{mn} modes having $n > 0$ are eliminated. This is accomplished by making the TE_{01} mode cutoff frequency just above the fourth harmonic reject band frequency range, say, 8.50 GHz. To accomplish this it is necessary to reduce the b dimension. When this is done, the only modes that can propagate at the fourth harmonic frequency range are the TE_{10}, TE_{20}, TE_{30}, TE_{40}, TE_{50}, and TE_{60} modes.

The remaining six possible modes of propagation can be reduced to four by reducing the waveguide width from 10.9 to 8.8 cm (4.3 to 3.45 in.). The fundamental frequency band will still propagate efficiently since this is essentially a WR-340 waveguide. Thus, only the TE_{10}, TE_{20}, TE_{30}, and TE_{40} modes can exist at the fourth harmonic frequency range if a primary waveguide having cross-sectional dimensions of 8.8 by 1.75 cm (3.45 by 0.69 in.) is chosen.

It is necessary to consider the power-handling capability of this reduced-size waveguide. The theoretical breakdown power of a rectangular waveguide in terms of waveguide dimensions, frequency, and field strength can be written as

$$P = 1.33 \times 10^{-3} \, ab \, (\lambda/\lambda_g) \, E_{rms}^2$$

where

a and b = waveguide dimensions

λ = free space wavelength

λ_g = guide wavelength

E_{rms} = breakdown electric field strength

The practical breakdown power level for 8.8×1.75-cm (3.45×0.69-in.) cross-section waveguide taking into account all the derating factors is

$$P = 4.63 \left(\frac{1}{2.10}\right)\left(\frac{1}{1.7}\right)\left(\frac{1}{1.25}\right)(0.73) = 445 \, kW$$

This value is obviously unsatisfactory since the filter has to handle 500 kW.

However, this problem was circumvented by going to a configuration of two reduced-dimension waveguides in parallel. This is accomplished by placing a septum plate parallel to the broadwalls so that the waveguide dimensions on each side of the septum plate are 8.8×1.75 cm (3.45×0.69 in.).

Since there was an adequate safety factor in power-handling capability, the height of the waveguides on either side of the septum was reduced to 1.54 cm (0.605 in.) to improve coupling to the secondary waveguides. Secondary stubs having dimensions of 0.79×1.81 cm (0.312×0.711 in.) were chosen. Taking this into account in addition to the height reduction yields a calculated power handling capability of

$$P = 2 \, (445) \left(\frac{0.605}{0.690}\right)\left(\frac{2.10}{2.54}\right) = 645 \, kW$$

which is a 29% safety factor. Past experience has shown that these calculations are quite conservative so that this design was considered reasonable. The filter utilizes 56 secondary stubs on each side arranged in a four-across array spaced at 2.83 cm (1.113 in.), which is 3/4 guide wavelength for the TE_{10} and TE_{20} modes at the reject band frequency range. The short circuits for the stubs are adjustable and are locked mechanically in place after adjustment.

IV. Plans

In the next reporting period, tests will be conducted to determine the overall performance with the X-band TWM receiver.

Reference

1. Leu, R. L., "400-kW Harmonic Filter," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. VII, pp. 131–135. Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1972.

Table 1. X-band filter specifications

Passband:	
Frequency range	2.100–2.120 GHz
Insertion loss across frequency range	0.05 dB maximum
Input VSWR across frequency range	1.05:1 maximum
Power capacity	500 kW CW minimum
Stopband (fourth harmonic):	
Frequency range	8.400–8.480 GHz
Attenuation across frequency range (all modes)	40 dB minimum
Power level	1 W
Noise generation	Arcing, corona, break-down, and other noise generating phenomena, excluding thermal noise, shall not exceed -180 dBm/Hz in frequency range 2.270–2.300 and 8.40–8.50 GHz
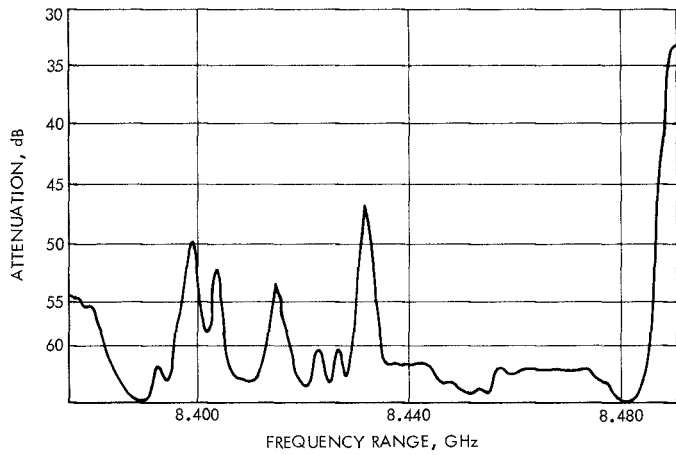
Fig. 1. Attenuation vs frequency TE$_{20}$ mode
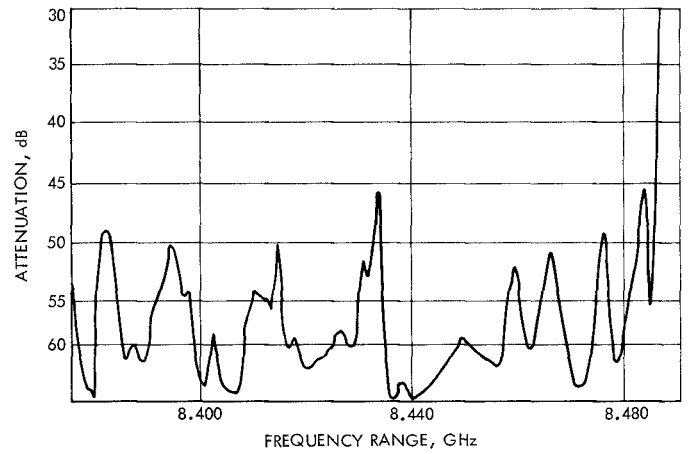
Fig. 2. Attenuation vs frequency TE$_{10}$ mode
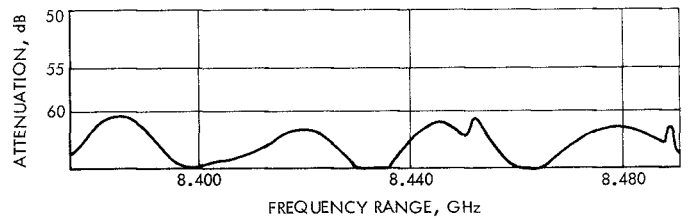
Fig. 3. Attenuation vs frequency TE$_{01}$ mode